Ecology

E. bos favours well drained sandplain country where it can burrow easily. On the islands between Dongara and Lancelin, it is mainly found in dune-sand locations away from the rocky areas where *E. pulchra* is so common. However, on islands where it is the only *Egernia* representative it frequently burrows under rocks in sandy situations except when there are other species competing for such sites (Ford, 1963). On Bernier Island, it has not been observed to burrow (Douglas and Ride, 1962), but in view of the species' habits in other parts of its range, it probably does.

Nomenclature

I have used the nomenclature proposed by Storr (1960). It is possible, however, that *bos* is a sub-species of *E. whitii* (Storr, pers. comm.). Glauert (1960) and Douglas and Ride (1962) discuss *bos* under the name of *E. whitii*.

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ASSOCIATION OF NESTING SEA-BIRDS AND VEGETATION TYPES ON ISLANDS OFF CAPE LEEUWIN, SOUTH-WESTERN AUSTRALIA

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INTRODUCTION

Hamelin, St. Alouarn and Seal Islands off Cape Leeuwin in the extreme South-West of the Australian continent illustrate the manner in which colonies of nesting seabirds can alter the composition of the vegetation. These islands are less accessible than most of those on the west coast and relatively little disturbed by man. The only reference to them in the biological literature is of a visit made by John Gilbert in December 1842 to "one or more of the islands off Cape Leeuwin"

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(unnamed) where he recorded breeding colonies of Fleshy-footed Shearwaters and White-faced Storm-Petrels (Whittell, 1942).

Hamelin I., where the vegetation is least modified by birds, lies approximately 12 miles north of the Cape off the west coast, and occupies 19 acres. Seal I., where it is most modified, lies ¾ mile east of the Cape where the Indian and Southern Oceans meet, and occupies 10 acres. St. Alouarn I., which is in an intermediate position as regards avifauna, flora and geology, lies 4 miles south-east of the Cape, and occupies 21 acres.

Detailed field reports of the three islands have been lodged in the University Botany and Zoology departments and the C.S.I.R.O. Division of Wildlife Research Laboratory in Perth, W.A.

GEOLOGY AND SOIL

Geology

Seal I. is composed of Precambrian granitic gneiss from which any pre-existing cap of limestone has been eroded away. The gneiss crops out as smoothly rounded shoulders running more or less north to south and rising to a maximum height of 29 ft. (9.2 m.) but most is lower. A steeply sloping beach of broken shells occurs between two gneiss promontories in the south but there were no accumulations of sand when the island was investigated in November, 1959.

St. Alouarn I. has a similar basis of granitic gneiss but this is overlain by a substantial capping of aeolianite or consolidated dune limestone of late Pleistocene age rising 86 ft. (26.5 m.) above the sea. Differential weathering has caused the softer aeolianite to recede from the coast, particularly on the more exposed south, so that the entire shoreline consists of fairly level expanses of the more resistant gneiss. Beaches of large shell fragments have accumulated in declivities along the south side and a small sandy beach protected by reefs occurred in the west at the end of the 1959 winter.

Hamelin I. consists entirely of sculptured aeolianite which has been eaten into by the sea to form stacks and reefs. It rises 105 ft. (32.3 m.) above sea level and gives protection at times to ephemeral sandy beaches, the most extensive of which are on the east and north-east.

Soil

There is little mineral soil on Seal I., but sufficient plant and animal detritus has accumulated to provide a suitable burrowing habitat for a large population of Fleshy-footed Shearwaters. Much of this consists of a coarsely pulverised shell grit with varying amounts of incorporated plant material, but it ranges from almost unmodified shell fragments in the south to thin crusts of fairly pure peat in hollows of the gneiss on the north.

Aeolianite outcrops are scattered throughout St. Alouarn I. and the soil between is more finely pulverised, sandier and deeper than on Seal I. Considerable deposits overlie the coastal gneiss at the foot of the eroding limestone capping, but it is probable that most of this material is derived from the calcareous rock above. Deposits of unmodified shell fragments and pure peat are unimportant.

TABLE 1.—RELATIONSHIP OF COLONIAL SEABIRDS TO HABITAT

	Island	Hamelin I.	St. Alouarn I.	Seal I.
Habitat	Rock	Aeolianite	Aeolianite capping on Gneiss	Granitic Gneiss
	Soil	Deep sand	Shallow sand	Shell Grit
	Vegetation	Sclerophyllous shrubs	Succulent-leaved shrubs	Succulent herbs and introduced grasses
Number of bird species	Surface-nesting birds (Silver Gull, Caspian, Crested and Fairy Terns)	1	0	4
	Burrowing birds (Fairy Penguin, Storm-Petrel, Fleshy-footed and Little Shearwaters)	0	3	2
	Crevice-nesting birds (Bridled Tern, Rock Parrot)	1 or 2*	1	2
	Total	2 or 3*	4	8

*Bridled Terns recorded on offshore stack in 1955, not in 1959.

Considerable sand deposits occur on Hamelin I., forming immature soils with a low humus content. Blowouts have occurred in the west where depths of several metres of sand have been scooped out to expose the underlying limestone, Much of this latter is only partially consolidated and crumbles readily back into the dune sand from which it originated. Local travertinisation gives a more resistant, undermined surface in places, but this rock generally is much softer than the underlying horizons which project to form reefs and stacks. Large deposits of land snail shells *(Bothriembryon kingi)* are left on the surface where the finer particles have blown away. (These are rare on St. Alouarn I. and were not seen on Seal I.)

BIRDS

The Habitat

Table 1 shows the totals of colonial-nesting seabird species recorded in the first week of November 1959, in relation to the predominant vegetation cover on the island concerned. It will be seen that the greatest number of species of colonial seabirds occurs on the smallest, least heavily vegetated island and the smallest number on the largest, most heavily vegetated island.

The most characteristic shrub-nester of more northerly islands, the Large Pied Cormorant *(Phalacrocorax varius)*, is rare in the south where only burrowing birds are associated with shrubs and all surface nesters occur in open, herbaceous vegetation.

The dense, sclerophyllous shrub community which covers most of Hamelin I. attracts no seabirds but the more homogeneous, suc-

culent-leaved shrub community of St. Alouarn I. gives shelter to numbers of burrowing petrels, although sand depth is often inadequate for burrowing and many of these nest in crevices of the aeolianite.

The herbaceous and partially ephemeral vegetation of Seal I. provides a habitat for a much denser population of seabirds, both burrow dwellers and surface nesters.

Range of Species Recorded

Fleshy-footed Shearwater *(Puffinus carneipes).*—The breeding range of this southern species extends only from the Recherche Archipelago in the east to the "Cosy Corner" Is. in Hamelin Bay and no traces were seen on Hamelin I., just north of "Cosy Corner." Gilbert's 1842 record for "islands off Cape Leeuwin" gave no specific locality and it had been assumed that it referred to St. Alouarn I. on which large numbers of burrows had been observed from the air (Serventy and Whittell, 1951). No trace of this species was observed there, however, although birds were very much in evidence on Seal I. where they were crowing noisily underground in newly cleaned out burrows or crouched beneath the inadequate cover of boulders. There appear to be more than 500 pairs breeding on the island. The St. Alouarn burrows were not newly excavated and evidently belonged to a species with a different seasonal breeding cycle.

This shearwater was not observed in shrub communities, birds burrowing in a dense mat of *Carpobrotus rossii* on the "Cosy Corner" islands and in *Carpobrotus* or annual growths of grass (*Lolium loliaceum* and *Hordeum leporinum*) on Seal I.

Little Shearwater or **Allied Petrel** *(Puffinus assimilis).*—The majority of the St. Alouarn burrows appeared to belong to Little Shearwaters. The nearest recorded nesting localities of this species were on Eclipse I., 200 miles along the south coast to the east, and Parakeet I., 200 miles along the west coast to the north. Only 6 burrows had been recorded on Parakeet I. (a rock but 1/3 acre in extent) and the next known breeding site was a further 140 miles along the coast, north of Jurien Bay.

This species is a winter breeder, the young not having been seen in burrows after early November on Eclipse I. (Serventy and Whittell, 1951). Only one living specimen was seen on St. Alouarn I. on November 4, 1959, this emerging from a burrow and making its way overland to the sea, but several fresh carcases were found.

Burrows are intermediate in size between those of Fleshy-footed Shearwaters and White-faced Storm-Petrels. They occur in both rocky and sandy areas, and among *Rhagodia baccata/Nitraria schoberi* scrub or in mats of coastal succulents (*Calandrinia calyptrata, Carpobrotus rossii*, etc.).

White-faced Storm-Petrel *(Pelagodroma marina).*—Storm-Petrels, recorded by Gilbert in December 1842, are summer breeders and had not taken up residence by the first week of November, but burrows which almost certainly belonged to this species were found on the north-east of St. Alouarn I. in a *Calandrinia* community. The burrows were of narrow diameter with thin roofs which caved

in underfoot to reveal their tortuous windings. Curtains of the annual *Calandrinia* had partially covered their entrances since they were vacated about 8 months previously.

Blue or **Fairy Penguin** *(Eudyptula minor).*—Penguins are generally distributed around this part of the coast and adults and almost fully fledged young were commonly seen in burrows and crevices on Seal I. and St. Alouarn I. in all types of vegetation. None was found on Hamelin I.

Bridled Tern *(Sterna anaethetus).*—Bridled Terns have greatly increased in numbers during recent years (V. Serventy, personal communication) and it appears that they may be extending southwards. Gould (1865: 411) records them for the Abrolhos Is., approximately 500 miles to the north and Serventy and Whittell (1951) for a series of islands between the Kimberley Division to as far south as the "Cosy Corner" islands about 10 miles N. of Cape Leeuwin. Their presence on Seal I. east of Cape Leeuwin (see also Storr, 1959), where they were not recorded by Gilbert who was in the area during their breeding season in 1842, indicates a slight further extension of their range to the south coast. The island probably represents a new type of habitat, as previously recorded sites are on limestone which weathers into angular shelves and crevices often overshadowed by *Nitraria schoberi* or other vegetation. On Seal I. the birds (which had apparently not yet started to lay) were inhabiting crevices beneath the smoothly rounded gneiss where there were no bushes to give cover. 100-200 birds were recorded on Seal I. but none were seen on the two limestone islands. John Warham (personal communication) recorded birds and 4 eggs on a stack off the N. end of Hamelin I. in December 1955, however.

Caspian Tern *(Hydroprogne caspia).*—Caspian Terns are generally distributed around the coast but the nearest specific breeding sites recorded by Serventy and Whittell (1951) are *c.* 120 ml. E. (Nornalup) and *c.* 170 ml. N. (Safety Bay).

These birds are often solitary nesters but 36 nests occurred together on the north-west corner of Seal I., 5 chicks hatching during the morning of November 4, 1959. Just prior to these hatchings the percentage of eggs and chicks in nests was as follows, all but one of the chicks being located in the most densely populated part of the colony which had evidently been established first. Eggs: 17% of nests contained 1 egg; 41%, 2 eggs; 3%, 3 eggs. Chicks: 5% of nests contained 1 chick; 5%, 2 chicks; 3%, 3 chicks. Vacated or deserted nests, 25%.

Fairy Tern *(Sterna nereis).*—The Fairy Tern is again generally distributed around the coast but the most southerly breeding habitat recorded previously was Safety Bay, 170 miles to the north.

At the top of the southern shell beach on Seal I. 35 nesting scrapes had been excavated and the first egg had been laid in one. All were within 1 m. of the fringing *Carpobrotus rossii* community.

Crested Tern *(Sterna bergii).*—About 500-1000 birds of this generally distributed species breed on Seal I. during the summer

(Horner, personal communication). A flock of several hundred was based on seaward rocks in the north-west adjacent to the Caspian Tern rookery in early November 1959.

Silver Gull *(Larus novaehollandiae).*—The Silver Gull is generally distributed, and the fact that the nearest previously recorded nesting sites were 160 and 30 miles away to east and north respectively is probably of little significance and due to the sparseness of observers. As elsewhere on the coast the population has been increasing side by side with centres of human settlement on the adjacent mainland. The latter augment the natural food supplies available for omnivorous scavengers and there is evidence that the Hamelin I. rookery, at least, is fairly new.

Two small colonies, one with almost fully fledged chicks, occurred on peninsulas of Hamelin I. and a larger colony of several hundred nests containing eggs and chicks of all ages occurred on Seal I. Small flocks amounting to many hundreds of birds, streamed out from the mainland around Augusta at dusk to roost on Seal I. but only a few stray birds were seen around St. Alouarn I.

Rock Parrot *(Neophema petrophila).*—Small flocks of Rock Parrots were present on all three islands although gneiss is apparently an unusual habitat. Birds were seen feeding on the seeds of *Carpobrotus rossii*, *Calandrinia calyptrata*, a species favoured by Brown Quail *(Synoicus ypsilophorus)* on the Bass Strait Islands, and *Cryptostemma calendula*. The parrots were scattering more of the *Cryptostemma* fruits than they consumed and they may be a factor in hastening the rapid spread of this South African weed around the coasts and islands.

VEGETATION

Summary of Controlling Factors

The nature of coastal vegetation is normally dependent on two groups of factors, viz.: climatic, with emphasis on exposure to wind and spray, and edaphic, with emphasis on the nature of weathering of rock and mobility of sand as well as the physical and chemical properties of the soil. Wherever seabirds congregate, however, there is evidence that their efforts over-ride and often completely mask the effects of the climatic and edaphic environment. The Hamelin-St. Alouarn—Seal I. series illustrates this principle to a nicety.

Climatic Effects. The suppressive effects of spray-bearing winds on vegetation are often more quantitative than qualitative on small islands, causing local dwarfing of the generally halophytic vegetation on the more exposed localities.

On the largest of the three islands (Hamelin), however, there is a fairly marked qualitative difference from the leeward to the windward side. Its vegetation is more varied than that of the two smaller islands, and probably represents a fragmented portion of the dune climax vegetation on the adjacent mainland. The leeward side is occupied by *Melaleuca parviflora* shrubs 3-4 m. high and grading back into a dense scrub (up to 3 m. high) with mixed dominants *(Agonis flexuosa, Myoporum insulare, Scaevola crassifolia,*

Spyridium globulosum and *Templetonia retusa).* In the tangled undergrowth *Acanthocarpus preissii* and *Clematis pubescens* predominate.

In more windswept habitats the scrub is mostly under 1 m. high and dominated by *Myoporum insulare*, a yellowish-leaved form of *Templetonia retusa* and *Pimelea ferruginea.*

Other abundant small shrubs are *Acacia cuneata, Acrotriche cordata, Boronia alata, Hibbertia cuneiformis, Leucopogon richei (=L. parviflorus), Melaleuca huegelii* and *Thomasia triphylla* with herbaceous species such as *Stylidium adnatum.*

On St. Alouarn I. there is a tendency for the coastal belt of herbaceous succulents to diminish on the sheltered side and for *Nitraria schoberi* to increase at the expense of the otherwise dominant *Rhagodia baccata* as the coast is approached, but this could be due to its preference for broken limestone talus as well as its affinity for sea salt.

The more open scrub of windswept eminences allows room for the light-demanding *Poa poiformis.* This is a characteristic rookery grass of southern Australian islands as far as Victoria and Tasmania but is unimportant on more northerly islands and illustrates the southern affinities of this flora with the *Poa* tussock vegetation of sub-Antarctic bird islands.

No plant zonation in relation to exposure could be traced on Seal I. apart from a slight tendency for the subordinate species of the *Carpobrotus rossii* communities to fade out in the more spray-washed areas.

Edaphic Effects.—The nature of the underlying rock seems to have a negligible effect on the vegetation, and the two contrasting rock types of the islands, calcareous aeolianite and granitic gneiss, bear almost identical floras under comparable conditions of bird occupation.

Thus *Carpobrotus rossii,* which dominates approximately half of the Seal I. gneiss, is also dominant on the gull-frequented aeolianite peninsulas of Hamelin I. and the heavily burrowed aeolianite soils of the "Cosy Corner" Islands. Exotic annual grasses *(Lolium loliaceum* and *Hordeum leporinum),* which dominate the remainder of Seal I., are common with *Carpobrotus* on the aeolianite of the bird islands in Safety Bay (= Shoalwater Bay) Gillham, 1961).

Similarities are equally apparent in floras unaffected by birds and Hamelin I. scrub is composed of species characteristic of both gneiss and aeolianite on the mainland.

On the more open mobile soils of Hamelin I. *Calocephalus brownii* and *Olearia axillaris* become locally important, as the more prevalent shrubs are ousted. (These two shrubby composites are also more tolerant of soil disturbance by birds than are other shrubs with the exception of the succulent-leaved *Nitraria* and *Rhagodia* which dominate the St. Alouarn flora). Where the sand remains fairly mobile, *O. axillaris* is characteristic of the final stages of dune succession, whether there are birds present or not.

Biotic Effects.—A close correlation between density of birds and vegetation type can be traced. Surface-nesting birds have a more deleterious effect on plants than have burrowing birds, because of the direct guano-fouling and trampling of herbage. Thus St. Alouarn I., which carries only burrowing birds, shows a flora which is intermediate between that of Hamelin I. and Seal I. whilst the flora of the small portions of Hamelin I. which carry surface-nesting birds has passed beyond this stage to the Seal I. type.

Bird populations seem to have been fairly static on Seal I. and St. Alouarn I. for sufficiently long for the ecosystem to have attained some degree of equilibrium. The gull colonies of Hamelin I., on the other hand, are sufficiently recent for traces of a former vegetation to persist and point to the earlier phases of the degenerative plant succession induced by birds.

The flora of the three islands is listed in the appendix table where plants have been allocated into life form categories. The way in which these categories are related to the seabird population is illustrated in Fig. 1 and Table 1. (N.B. there is no evidence of fires or grazing mammals on the islands investigated.)

It will be seen that the climax flora unaffected by birds, as exemplified by Hamelin I., consists primarily of native perennials with sclerophyllous shrubs as the predominant life form. The severely modified flora of a densely populated bird rookery, as exemplified by Seal I., shows a preponderance of annual species, many of them aliens or succulents, and a complete absence of both shrubs and sclerophylls. The figures graphed represent the number of species in each life form. Had an estimate of the percentage ground

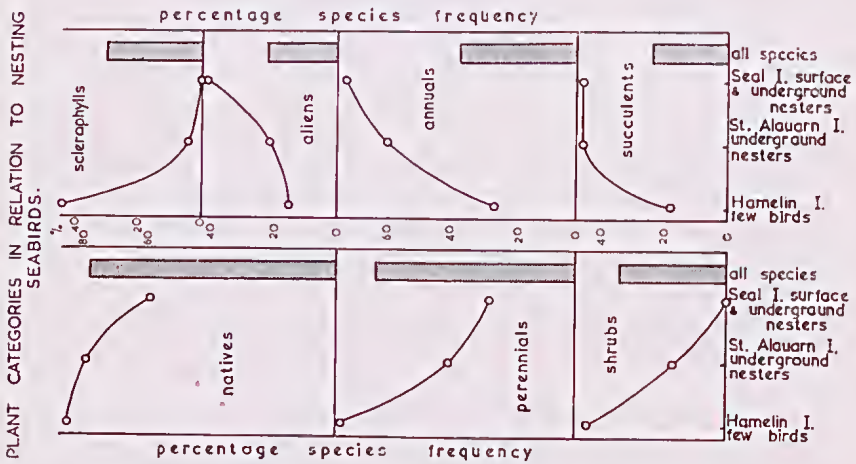

Fig. 1.—Diagram to show decrease of plant natives, perennials, shrubs and sclerophylls and increase of aliens, annuals and succulents with increasing bird activity. Figures graphed represent the number of species in each category expressed as a percentage of the total number recorded on the island concerned. Columns show equivalent figures for the flora of the 3 islands together (74 spp.).

cover of each group been attempted, the trends would have appeared even more striking.

The distribution of alien species is of particular interest, as Hamelin I., which shows the smallest number, is the only island on which man is likely to have had much influence. It is not only more accessible than the other two, but carries an automatic lighthouse. It is around the latter and beneath the flying fox leading to it from the eastern shore, that most of the aliens are congregated, and one of these, *Vulpia brevis?*, is a new state record and fairly obviously introduced by man.

Gulls have been proved effective introducers of alien weeds (Gillham, 1956) and 41% of the total flora of Seal I. are introduced species. The opening out, fertilisation and annual disturbance of the plant community favours the establishment of "weeds" so these thrive better on the more remote St. Alouarn I. than on Hamelin I., although the bird population there consists of species which feed at sea and have no opportunity of bringing new plants to the area.

Vegetation associated with Burrowing Birds on St. Alouarn I.

Superficially the vegetation of the shearwater rookery which occupies the whole of St. Alouarn I. resembles the unmodified climax vegetation of Hamelin I. in being shrubby, but specifically it is very different. The normal indigenous and fairly heterogeneous community of sclerophyllous shrubs as seen on Hamelin I. is here replaced by a homogeneous community of succulent- or silvery-leaved shrubs consisting of only four species, one of which is rare. There is less diversity in relation to exposure to sea winds and fewer subordinates.

The two succulent-leaved species are dominant, *Rhagodia baccata*, throughout the inland part and *Nitraria schoberi* on the cliffs. Of the two silvery-leaved composites *Olearia axillaris* is much the commoner, *Calocephalus brownii* rare and coastal in its distribution. *O. axillaris* is associated with *R. baccata* in the less densely populated rookeries of Wedge-tailed Shearwaters *(Puffinus pacificus)* on Carnac and Rottnest Is. further north but gets killed out locally on all three islands where burrow density increases. Where there are no birds, but where the sand remains mobile, it often dominates a vegetation in which the succulents are rare.

In these areas on St. Alouarn I. there is a local increase of herbaceous species, principally *Carpobrotus rossii, Lavatera plebeja* and *Poa poiformis*, which are representative of a more degenerate phase of the plant succession.

Herbs are dominant around the base of the aeolianite cliffs where sand has accumulated to give a more favourable burrowing medium. Not only is guano deposition higher in this more heavily populated zone, but blown sea spray would add further to the concentration of salts in the soil solution and consequent modification of the flora.

The principal plants of this zone are *Lavatera plebeja* and the four succulents, *Apium prostratum* (a short erect form very different from that of eastern states and New Zealand rookeries), *Carpo-*

brotus rossii and *Threlkeldia diffusa*. *Sonchus oleraceus* and other aliens are locally abundant.

An open area on the summit ridge is apparently used as a taking off place by shearwaters. Tracks converge from various parts of the surrounding rookery and the vegetation has become very worn. Shrubs have been killed back and a transition zone of *Poa poiformis* leads into an ephemeral community which is composed of annuals. Chief of these are the three aliens *Polycarpon tetraphyllum*, *Sonchus oleraceus* and *Stellaria media*. Others are *Calandrinia calyptrata*, *Crassula spp.*, *Parietaria debilis* and *Sagina apetala*.

Vegetation associated with Burrowing Birds on Seal I.

There are no shrubs on Seal I., where the vegetation consists solely of the less advanced herbaceous phases of the succession. The least degenerate types occur in areas occupied principally by burrowing shearwaters, with gulls and terns fairly sparse; the most degenerate flora is associated with the gulls and terns in the north-west and occurs locally near the heavily fouled entrances of penguin burrows. There is no doubt, however, that the proximity of the surface-nesters, particularly of the weed-distributing gulls, influences the vegetation of areas other than those on which they actually nest.

The least exotic communities are dominated by *Carpobrotus rossii* which forms a practically closed sward on the least hospitable substrata. The only subordinate species seen on the scarcely modified shell fragments of the south were small plants of *Apium prostratum* and *Lolium loliaceum*, but most of these two insecurely rooted annuals had been dislodged by excavating shearwaters during the recent cleaning-up of burrows prior to egg-laying.

On the more finely pulverised shell grits with a reasonable humus content *Cotula coronopifolia* occupies the peaty drainage hollows and *Lepidium foliosum*, *Apium prostratum*, *Sonchus oleraceus* and other species occur.

Nearer the main gull colony and throughout the centre of the island this type of substratum bears a fairly thick but broken sward of *Lolium loliaceum* overtopped by flowering *Lavatera plebeja*. *Carpobrotus rossii* and *Sonchus megalocarpus* are important. There were 13 species and percentage ground cover of the most important was as follows:

TABLE 2

Species	Main Community	Southern Margin
Lolium loliaceum	55%	50%
Lavatera plebeja	35	10
Carpobrotus rossii	—	20
Sonchus megalocarpus	—	15
Lepidium foliosum	5	—
Bare	5	5

On the most mature, organic-rich, shell grit soils of the western shearwater colony where it abuts onto the main gull and tern areas *Hordeum leporinum* is co-dominant with the *Lolium*. This is a

characteristic coprophilous alien of bird islands. *Cotula coronopifolia* and *Carpobrotus rossii* are invading from the peats and shell deposits respectively and *Lepidium foliosum* is frequent.

Vegetation associated with Surface-nesting Birds on Seal I.

Two types of community could be distinguished in the tern and gull colonies of the north-west but these intergraded with each other. One could be designated as representing a late stage of degradation of the indigenous flora, the other as representing an early phase of its recovery after the logical end point of bare soil had been reached.

In the one instance depauperate *Carpobrotus rossii*, *Calandrinia calyptrata*, *Lavatera plebeja*, *Lepidium foliosum* and *Apium prostratum* were receding to leave large tracts of bare ground on which a few aliens were becoming established. In the other instance the community was essentially an annual one, dominated by the introduced rye and barley grasses (*Lolium loliaceum* and *Hordeum leporinum*) but with seedlings of the native perennials, *Carpobrotus*, *Lavatera* and *Lepidium*, becoming established.

It is evident that degenerative and regenerative processes occur alongside each other, according to local fluctuations in the intensity of manuring and trampling, but that the flora gets no chance to advance beyond these lowly seral phases.

Table 3 shows the percentage cover of plants in one of the most disturbed parts of the community, together with percentage frequency of species occurring in actual contact with 36 Caspian Terns' nests and 50 Silver Gulls' nests.

The preponderance of *Lepidium* besides nests in a *Carpobrotus* dominated community is paralleled in seabird colonies in the eastern states. It may indicate only the preference of the birds for this taller plant which provides better "cover" for the nest, but survival of *Lepidium* in heavily fouled areas where *Carpobrotus* is killed out indicates that it is the more coprophilous of the two.

In Western Australia, as in Victoria and Tasmania, *Lepidium foliosum* and *Lavatera plebeja* are common on bird islands but seldom seen on the mainland.

TABLE 3

Species	Community as a whole (% ground cover)	Species by terns' nests (% frequency)	Species by gulls' nests (% frequency)
Bare rock	40%	—	—
Bare shell grit	40	—	—
Carpobrotus rossi	7	39%	22%
Hordeum leporinum	3	5	8
Lavatera plebeja	3	22	30
Lepidium foliosum	3	59	24
Calandrinia calyptrata	2	25	16
Lolium loliaceum	1	22	42
Apium prostratum	0.5	22	4
Cotula coronopifolia	0.5	5	6
Parietaria debilis	—	—	4

The two introduced grasses are commoner by the nests of shore-feeding gulls than by those of fish-eating terns.

Floristic Retrogression caused by Seabirds on Hamelin I.

The seabird populations of St. Alouarn and Seal Is. are so well established that no trace of a former sclerophyllous vegetation matching that of the adjacent mainland has survived. Colonisation by gulls on Hamelin I. is sufficiently recent for relicts of both original and transitional communities to be recognisable.

The end point of the retrogressive plant succession is the same in the sheltered south-west and the exposed north-west, except that the latter community is more open than the former, but the starting point is different.

The vegetation of south-eastern promontories unaffected by gulls is co-dominated by sclerophyllous shrubs (*Melaleuca parviflora and Templetonia retusa*, with *Pimelea ferruginea, Acacia cuneata* and *Boronia alata* less common.)

The less stable vegetation of the south-eastern gull promontory is dominated by *Carpobrotus rossii* with earlier successional phases represented as follows:—

(i) *Sclerophyllous shrubs.*—Dead trunks and branches of a former shrub community, many still in situ, were scattered through the area, partially rotted and overgrown. All those examined were referable to *Templetonia retusa*, although it may be assumed that the original scrub was mixed as in the adjacent "control areas." It is not known whether this indicates a more persistent survival of living *Templetonia* plants or a slower disintegration of dead ones.

(ii) *Greyish, non-succulent shrubs.*—This group was represented by small scattered *Calocephalus brownii* bushes, some dead and overgrown by *Carpobrotus*, some dying. Many of the dead clumps had old nests beneath their lower branches.

(iii) *Sclerophyllous monocotyledons.*—A few dead clumps of *Scirpus nodosus* protruded from the *Carpobrotus* mat but there was no trace of *Lepidosperma gladiatum*, which was frequent beyond the confines of the rookery, and is able to survive well in colonies of burrowing birds elsewhere.

(iv) *Succulent-leaved shrubs.*—These were represented by a few clumps of *Rhagodia baccata*, small, prostrate and with yellowish leaves. They were in better condition than the *Calocephalus* clumps but by no means robust.

(v) *Succulent perennial herbs.*—This group included the dominant *Carpobrotus rossii*, the second most abundant species, *Threlkeldia diffusa*, and the only *Salicornia australis* recorded on the island.

(vi) *Ephemerals.*—*Hymenolobus procumbens* occurred where the somewhat worn *Carpobrotus* was yielding ground but the latter had not degenerated sufficiently for the final annual phase of the retrogression to have assumed any importance.

Under the more rigorous conditions suffered in the north-west, the initial phases shown by the control areas consisted of an open *Calocephalus brownii* scrub with sclerophyllous monocotyledons almost as important as the more generally distributed sclerophyllous shrubs. The chief subordinate species were *Exocarpus spartea, Olearia axillaris, Pimelea ferruginea, Scaevola crassifolia, Lepidosperma gladiatum, Poa poiformis, Scirpus nodosus* and *Senecio lautus*. The final phases consisted of a very open community of succulent herbs dominated by *Carpobrotus*.

Significance of Vegetation Changes in Relation to Birds and Soil

Birds. It is evident from the Hamelin I. sequence cited above that vegetational phases (v) and (vi) in which nesting gulls are most commonly found are far removed from the type of habitat which the birds originally occupy when taking up a new area. Which type of habitat represents the optimum from the birds' point of view is difficult to say, but both are obviously suitable.

It seems likely that the more open habitat, which is the inevitable outcome of prolonged occupation by any but a small population of birds, is to be preferred. When a new territory is taken over this type is seldom available and the gulls must, perforce, nest among shrubs. On Hamelin I., however, where they have the choice of both shrubby and open promontories, they remain on the latter, although not averse, as are burrowing birds, to moving from one site to another in successive seasons. This may thus be an example of breeding birds leading to an "improvement" in their habitat instead of,

TABLE 4

Dominant Plant Life Form	Principal Genera	Associated Seabirds	Island
(i) Sclerophyllous shrubs	Acacia, Agonis, Boronia, Dodonaea, Hibbertia, Leucopogon, Melaleuca, Myoporum, Pimelea, Scaevola, Templetonia	None	Hamelin I.
(ii) Greyish-leaved shrubby composites	Olearia, Calocephalus	Burrowing birds	St. Alouarn I.
(iii) Sclerophyllous monocotyledons	Poa, Lepidosperma, Scirpus	None	Hamelin I.
(iv) Succulent-leaved shrubs	Rhagodia, Nitraria	Burrowing birds	St. Alouarn I.
(v) Perennial herbs, mostly succulent	Carpobrotus, Threlkeldia, Lepidium, Lavatera	Surface-nesting birds	St. Alouarn I.
(vi) Annual herbs, mostly aliens	Lolium, Hordeum, Apium, Calandrinia, Polycarpon, Sagina, Stellaria, Sonchus, Cryptostemma	Surface-nesting birds	Seal I.

as is more usual, causing progressive destruction until a general exodus to a new site is necessitated.

Table 4 summarises the range of habitats associated with underground and surface nesters on the three islands. The situation at present indicates that burrow dwellers have a wider range of habitat tolerance than have surface dwellers, but in view of the gulls' ability to colonise scrub, this is obviously not a true picture.

What the table actually illustrates is the differential effects of the two groups of birds in the modification of their habitat. When gulls colonise scrub the community becomes converted to a herbaceous one; when petrels or other burrowing birds colonise scrub the nature of the component species changes but the shrubby habit remains except where the population is locally concentrated, as on tracks, or is associated with surface-nesting birds.

Soil, and floristic affinities with islands off S.E. Australia. One of the most striking features emerging from a study of the species list in the appendix table is the close affinity of the two rookery floras with those of Victoria and Tasmania 2,000 miles away.

Only 7% and 9% respectively of the St. Alouarn and Seal I. species are not known to occur in Victoria. These three species (*Chenopodium anthelminticum, Cotula cotuloides* and *Arctotheca nivea*) are unimportant in the western rookeries and each is paralleled by a closely related species in eastern rookeries. The only major differences between the rookery flora of east and west appears to be the greater abundance of *Poa poiformis* in the east, the replacement in the east of some of the *Carpobrotus rossii* by the closely related *Disphyma australe* and the unimportance in the east of *Nitraria schoberi* which is more characteristic in Victoria of saline swamps (Ewart, 1930).

Conversely the unmodified Hamelin I. flora has little in common with unmodified island floras of south-eastern Australia apart from the dominant life form of selerophyllous shrubs. Of the Hamelin I. species 44% appear not to be recorded for Victoria, and these include practically all the important shrubs. Many of the Hamelin I. species common to both sides of the continent are herbaceous and play only a minor role in the community structure.

In view of the very different soil types and geographical isolation of the two areas, these differences are to be expected. The fact that they do not occur in the rookeries points to the significance of seabirds in producing a uniform (though seasonally fluctuating) environment tolerated by but a specialised flora. This flora is fairly constant from one area to another in spite of long stretches of intervening coastline with no bird colonies.

The country rock in most of the west coast bird colonies of Western Australia is calcareous aeolianite except on Seal I. which carries a calcareous deposit of shell fragments. The country rock of the bird colonies of south-eastern Victoria is granite of varying types. Both yield a sandy soil but this is strongly alkaline in the west and acid in the east (Smith, 1951, records a pH range of 8.4-9.3 in sand overlying limestone or shell fragments in the Leeuwin

Association and McArthur, 1957, found pHs below 8.0 only in the upper organic horizons of the aeolianite islands off Fremantle).

Much of this divergence of soil reaction is eliminated in the rookery soils of east and west where guano deposits produce greater uniformity.

The derived soils of the indigenous coastal heaths of both Eastern and Western Australia are heavily leached (Specht and Rayson, 1957, and Fairbridge and Teichert, 1952). Where guano is deposited the lost nutrients are being constantly replaced and the effects of leaching are nullified. It is the high fertility level brought about by nitrogenous and phosphatic components of guano which is thought to be largely responsible for the replacement of the indigenous sclerophylls by more demanding plants (cf. the death of heath species which occurs when fertilisers are added to newly reclaimed farmland).

Fairbridge and Teichert (1952) working on the Hamelin I. and Hamelin Bay soils stated that the test for phosphate was negative in every case.

In the Garden I. habitats most closely resembling the smaller southern islands, McArthur (1957) recorded 0.07-0.04% total nitrogen, whilst McArthur and Bettenay (1958) recorded 0.22% in Quindalup soils near Busselton. These readings are not particularly high, even by Western Australian standards, and it is to be expected that guano deposits would lead to the establishment of a more nitrophilous flora than that normally present on such soils.

ACKNOWLEDGMENTS

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APPENDIX

COMPOSITE SPECIES LIST FOR THREE ISLANDS OFF CAPE LEEUWIN

"H" signifies that specimen has been determined at the W.A. Herbarium.

SPECIES Aliens marked X	Plant Category					Island		
	Longevity		Habit					
	A	P	F	W	X			
	Annual	Perennial	Succulent	Woody	Sclerophyll	Hamelin	St. Alouarn	Seal
X Vulpia membranacea (L.) Dum.	A?					H		
Serrafalcus arenarius (Labill.) C. A. Gardn.	A						H	
X Briza maxima L.	A					H		
Poa australis R. Br.		P			X	H		
Poa poiformis (Labill.) Druce		P			X	H		
Stipa variabilis Hughes.		P				H		
X Cynodon dactylon (L.) Pers.		P						H
X Lolium loliaceum (Bory et Chaub.) Hand.-Mazz.	A							H
X Avena sativa L.	A					H		
Parapholis incurva (L.) C. E. Hubbard	A					H		
X Hordeum leporinum Link.	A						+	H
Scirpus nodosus Rottb.		P			X	+		
Lepidosperma angustatum R. Br.		P			X	H		
L. gladiatum Labill.		P			X	H		
Acanthocarpus preissii Lehm.		P			X	+		
Parietaria debilis Forst. f.	A						+	+
Exocarpus spartea R. Br.		P	(F)	W		H		
Rhagodia baccata (Labill.) Moq.		P	F	W		+	H	
X Chenopodium anthelminticum L.	A						H	
Threlkeldia diffusa R. Br.		P	F			+	H	
Salicornia australis? Banks et Soland.		P	F			H		
Carpobrotus rossii Schwantes		P	F			+	+	+
Tetragonia implexicoma (Miq.) Hook. f.		P	F			+		
X Cryophytum crystallinum (Linn.) N. E. Br.	A		F					+
Calandrinia calyptrata Hook. f.	A		F				+	H
C. polypetala Fenzl.	A		F			H	?	?
X Stellaria media (L.) Vill.	A						+	H
Sagina apetala Arduino	A						H	H
X Polycarpon tetraphyllum Loef.	A					+	+	H
Clematis pubescens Hueg.		P		W		H		

	SPECIES Aliens marked X	Plant Category: Longevity: Annual	Plant Category: Longevity: Perennial	Plant Category: Habit: Succulent	Plant Category: Habit: Woody	Plant Category: Habit: Sclerophyll	Island: Hamelin	Island: St. Alouarn	Island: Seal
	Lepidium foliosum Desv.		P	F				+	H
	Hymenolobus procumbens (L.) Nuttall.	A					H	H	
	Crassula colorata (Nees.) Ostf.	A		F				+	H
	C. macrantha (Hook f.) Diels & Pritzel	A		F				H	H
	Sollya fusiformis? (Labill.) Briq.		P		W	X	H		
	Acacia cuneata Benth.		P		W	X	H		
	A. cyclopsis A. Cunn.		P		W	X	H		
	Templetonia retusa (Vent.) R. Br.		P		W	X	H		
X	Medicago denticulata Willd.	A					H		
	Nitraria schoberi Linn.		P	F	W			H	
	Boronia alata Sm.		P	F	W	X	H		
	Phyllanthus calycinus Labill.		P				H		
	Poranthera microphylla Brongn.	A					H		
	Dodonaea aptera Miq.		P		W	X	H		
	Trymalium spathulatum (Labill.) Ostf.		P		W	(X)	H		
	Spyridium globulosum (Labill.) Benth.		P		W	(X)	H		
	Lavatera plebeja Sims.	A	P					+	H
	Thomasia triphylla (Labill.) J. Gay		P		W	(X)	H		
	Hibbertia cuneiformis (Labill.) Gilg.		P		W	X	H		
	Pimelea ferruginea Labill.		P		W	X	H		
	Melaleuca huegelii Endl.		P		W	X	H		
	M. parviflora Lindl.		P		W	X	H		
	Agonis flexuosa (Spreng.) Schau.		P		W		H		
	Apium prostratum Labill.		P					H	H
	Acrotriche cordata (Labill.) R. Br.		P		W	X	H		
	Leucopogon richei (Labill.) R. Br.		P		W	X	H		
X	Anagallis arvensis L.	A					+		
X	A. foemina Mill.	A					+		
	Samolus repens (Forst.) Pers.		P				H		
	Alyxia buxifolia R. Br.		P		W	X	+		
	Dichondra repens R. & G. Forst.		P				+		
	Myoporum insulare R. Br.		P	(F)	W	(X)	+		
	Isotoma scapigera (R. Br.) G. Don.	A					H		
	Scaevola crassifolia Labill.		P	(F)	W	(X)	H		
	Stylidium adnatum R. Br.		P			X	H		
	Olearia axillaris (D.C.) F. Muell.		P		W	(X)	H	+	
	Calocephalus brownii (Cass.) F. Muell.		P		W	(X)	H	H	
	Cotula coronopifolia L.		P	F				H	H
	C. cotuloides (Steetz) Druce	A		F				H	H
	Senecio lautus Sol.		P	(F)			+		
X	Cryptostemma calendula (L.) Druce	A							+
X	Arctotheca nivea (Linn.) Lewin.		P	(F)					+
	Sonchus megalocarpus (Hook f.) J. M. Black.	A		(F)			+		H
X	S. oleraceus Linn.	A					+	+	+

Total no. of spp. = 74	58	16	28	47	18	25	24	54	24	22
% of natives	78							85	79	59
% of introduced spp.		22						15	21	41
% of annuals			37					26	60	73
% of perennials				63				74	40	27
% of succulents					24			18	46	46
% of shrubs						34		44	17	0
% of sclerophylls							32	44	4	0

Note:— Symbols in brackets have been accorded half unit value in the construction of totals.

SUMMARY

Hamelin I., St. Alouarn I. and Seal I., off the south-western corner of the Australian continent, provide a striking example of the profound floristic modifications brought about by nesting seabirds. The flora of Hamelin I., where seabirds are marginal only, is a replica of that of the adjacent mainland and is co-dominated by 6-7 sclerophyllous shrubs. The similar soils of St. Alouarn I. are tunnelled by a vast population of petrels (**Puffinus assimilis** and **Pelagodroma marina**) and none of the sclerophyllous shrubs survive. The vegetation is fairly homogeneous and dominated by two coprophilous, succulent-leaved shrubs.

Seal I. is occupied by burrowing birds (**Puffinus carneipes** and **Eudyptula minor**), four species of terns and one of gulls and no shrubs survive. Succulent native herbs and exotic annual grasses share dominance. The course of this floristic degradation from shrubs to herbs can be traced on parts of Hamelin I. which have been recently colonised by Silver Gulls (**Larus novaehollandiae**).

The comparatively negligible influence of exposure and the indigenous soil type in bringing about these changes is discussed and parallels drawn between seabird rookeries on the calcareous aeolianite of Western Australia and the acid granite of S.E. Australia. The merits of the three principal vegetation types as nesting habitats are discussed. New breeding stations are recorded for certain of the seabirds.

ABLEPHARUS BUTLERI, A NEW SCINCID LIZARD FROM WESTERN AUSTRALIA

By G. M. STORR, Western Australian Museum.

Holotype: R20615 (in Western Australian Museum) collected by G. M. Storr and R. E. Moreau on June 28, 1963.

Type locality: 4 miles east of Leonora, Western Australia; lat. 28°52′ S, long. 121°23′ E.

Paratypes (all in Western Australian Museum): R18297 and R20684 (Yamarna, 64 mi. N.E. of White Cliffs), R20665-8 (White Cliffs), R18298 (Laverton), R18339 (6 mi. N.E. of Mt. Morgans), R15686 and R18340-4 (6 mi. S.W. of Mt. Morgans), R21164 (Youanmi), R18324-5 (Menzies), R18307 (12 mi. E. of Zanthus).

Diagnosis: Belongs to subgenus *Morethia* Gray and is most like *Ablepharus lineocellatus* Duméril and Bibron, from which it is distinguishable by its uniform dorsal coloration and by its supraciliaries, which form a narrow straight-sided series of 6 scales, the first of which is largest; whereas in *lineocellatus* the last three of the 5 supraciliaries are enlarged and penetrate deeply between the supraoculars.

Description: A terrestrial cryptozoic skink with well-developed limbs, each with five digits. Tail about 1½ times as long as head + body, which has a maximum length of 56 mm. Supraciliary ridge acute.